AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523
BIBLIOGRAPHIC INPUT SHEET

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Batch #31

1. SUBJECT CLASSIFICATION	A. PRIMARY: Agriculture	AA00-0000-G704
	B. SECONDARY: General--Korea Rep.	

2. TITLE AND SUBTITLE
On a national macro model linking Korean agriculture and non-agriculture

3. AUTHOR(S)
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4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1974	27p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Mich.State

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)
(In KASS working paper no. 74-3)

9. ABSTRACT

10. CONTROL NUMBER: PN-AAB-757	11. PRICE OF DOCUMENT
12. DESCRIPTORS: Korea Rep. Linkages Models Sector analysis	13. PROJECT NUMBER 14. CONTRACT NUMBER: CSD-2975 Res. 15. TYPE OF DOCUMENT

AID 590-1 (4-74)

ON A NATIONAL MACRO MODEL LINKING KOREAN AGRICULTURE AND NONAGRICULTURE

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KASS Working Paper No. 74-3

Korean Agricultural Sector Study

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22 August 1974

Revised 3 September 1974

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ON A NATIONAL MACRO MODEL LINKING KOREAN AGRICULTURE AND NONAGRICULTURE

INTRODUCTION

A major missing link in the KASS model as documented in KASS Special Report 9 is a national macro model linking the Korean agricultural and nonagricultural sectors. For efficiency, let's call it the Korean macro model; and let's add to the alphabet soup of KASS, KASM, RLP, GMP and SEAPA by abbreviating it KOMAC.

In this paper I will first briefly discuss the role KOMAC is to play in KASM. Then a tentative model to fill this role will be presented in some detail, including some preliminary observations on eventual operational linkage of KOMAC within KASM. Finally, the issues of data needs and the definition of sectors will be raised.

THE ROLE OF KOMAC

A general principle for drawing boundaries around a system for study is to exclude (i.e., treat as exogenous) those variables which influence the system but which are not, by safe assumption, influenced by the system. By this criterion, a number of input variables to an agricultural sector model from the nonagricultural sector must be treated endogenously as part of the system rather than exogenously, because they are in turn themselves influenced by agricultural sector variables to a degree that cannot be safely assumed away. Examples include urban income and employment and demand for raw materials for nonagricultural production. These variables determine demand for agricultural commodities and rural-urban and ag-nonag migration, thereby affecting ag sector growth. But ag sector growth, as ag income increases, determines ag and rural demands for consumer goods, capital equipment and production inputs, thereby stimulating nonag sector growth and nonag income, employment and raw materials demand. And so forth. The importance of these linkages was demonstrated by the Byerlee-Halter macro model component[1] of the Nigerian simulation model.

The linkages between KOMAC and KASM are Y_1, a vector of variables, passing from KASM to KOMAC, and Y_2, a vector of variables going the other way.

$$
Y_1(t) = \begin{bmatrix} POP_R(t) \\ POP_U(t) \\ OUTA(t) \\ DLA(t) \\ WA(t) \\ DEPCA(t) \\ AGIV(t) \\ AINP(t) \end{bmatrix} = \begin{bmatrix} \text{rural population — people} \\ \text{urban population — people} \\ \text{market value of total ag output— won/year} \\ \text{ag labor demand — man-hrs/year} \\ \text{ag wages — won/year} \\ \text{ag capital depreciation — won/year} \\ \text{ag net investment — won/year} \\ \text{ag input demand vector — won/year} \end{bmatrix}
$$

$$
Y_2(t) = \begin{bmatrix} YU(t) \\ YR(t) \\ YN(t) \\ YA(t) \\ TW_R(t) \\ TW_U(t) \\ DLN_R(t) \\ DLN_U(t) \\ PCDA_U(t) \\ PCDA_R(t) \\ PCDN_U(t) \\ PCDN_R(t) \\ PA(t) \\ PN(t) \\ P(t) \end{bmatrix} \quad \begin{bmatrix} \text{urban income -- won/year} \\ \text{rural income -- won/year} \\ \text{nonag income -- won/year} \\ \text{ag income -- won/year} \\ \text{rural wages -- won/year} \\ \text{urban wages -- won/year} \\ \text{rural nonag labor demand -- man-hrs/year} \\ \text{urban nonag labor demand -- man-hrs/year} \\ \text{per capita urban demand for ag commodities -- won/person-year} \\ \text{per capita rural demand for ag commodities -- won/person-year} \\ \text{per capita urban demand for nonag goods -- won/person-year} \\ \text{per capita rural demand for nonag goods -- won/person-year} \\ \text{ag price index} \\ \text{nonag price index} \\ \text{ag input price indices} \end{bmatrix}
$$

With Y_2, then, KASM has the information it needs to determine ag and nonag labor forces, rural-urban migration and population in each area, resulting mechanization and other ag responses to a shrinking labor force, rural and urban demands for the various ag commodities, and ag input demands. Preliminary observations on specific KASM-KOMAC linkage problems will be discussed in the last section.

A TENTATIVE KOMAC MODEL

The point of departure for this KOMAC model was the Byerlee-Halter model with improvements -- particularly in the consumption and investment components -- suggested by Byerlee[2] and my preliminary observations of the Korean context. In order to incorporate productive capacity constraints, the model is basically a programming model -- QP or LP (quadratic or linear) depending on the objective function used. If a justifiable objective function cannot be found, the alternative model presented -- derived from the programming model by converting the inequality constraints into a set of equations for simultaneous solution -- would be an appropriate one to use. If further investigations indicate capacity constraints can be safely ignored, the model can be greatly simplified.

At the center of KOMAC (Figure 1) is the production-consumption-investment programming component (PCI). In addition, there are price, labor and capacity components. The accounting component generates performance criteria and interfaces KASM and KOMAC. Finally, the foreign trade component provides import and export policy decisions either endogenously or via decision-maker interaction with the model.

Production-Consumption-Investment

It is assumed here that of the n sectors of the economy, sector number 1 is agriculture and the rest are nonagricultural sectors. In this way, there is a symmetry between KASM and KOMAC: the former disaggregates agriculture into 19 commodities and commodity groups and considers a

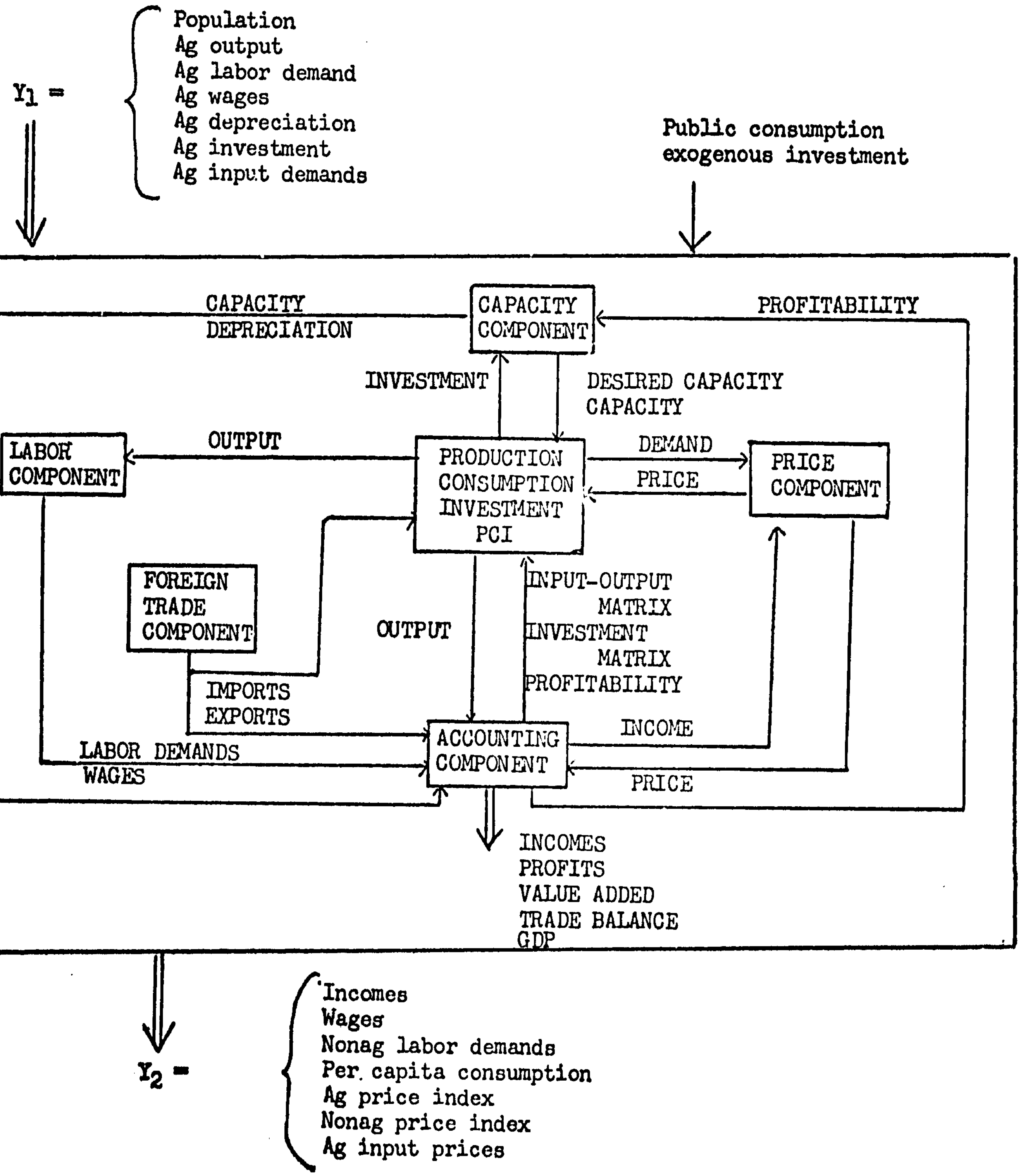

Figure 1

The KOMAC Model:
Principal Internal and External Linkages

single nonagricultural aggregate while the latter has n-1 nonag sectors and one ag aggregate. This symmetry will greatly facilitate the assurance of consistency between KASM and KOMAC. For example, it's much easier to be consistent when aggregating 19 KASM sectors into one than into 5 or 6, particularly in updating the input-output technology matrix. Furthermore, given detailed ag sector analysis in KASM, more than one ag sector in KOMAC would not be necessary unless a disaggregation of, for example, ag processing into crop processing and livestock processing, say, were required in order to capture important differences in the effects on these sectors of differential rates of growth of the crop and livestock sub-sectors.

Programming Formulation

PCI optimizes an objective function (to be discussed later) subject to capacity, consumption, investment and income constraints. The $(3n+2)x1$ decision vector is $X(t) = [CD_U(t)\ CD_R(t)\ IVN(t)\ S_U(t)\ S_R(t)]^T$, where CD_U and CD_R are vectors of urban and rural consumption, respectively, in won/year, IVN is a vector of endogenous investment, in won/year, to expand capacity in each of the n sectors of the economy, and S_U and S_R are urban and rural coefficients of the income component of demand used in the respective consumption functions to satisfy the income constraint.

The first constraint is the capacity constraint on production:

$$(1) \qquad OUT(t) \leq CAP(t),$$

i.e., output must not exceed capacity, in won/year[3]. Output is defined, using the current value of the input-output technology matrix A(t), in terms of the decision variables and exogenous components of final demand.

$$(2) \qquad OUT(t) = [I - (I-PMC(t))A(t)]^{-1} [(I-CMC(t))\,(CD_U(t) + CD_R(t) + CD_P(t)) + (I-IMC(t))B(t)\,(IVN(t) + IVX(t) + CKR^{-1}DEPC(t)) + XD(t)]$$

where PMC, CMC and IMC are determined in the foreign trade component (equations (45)-(47)) and are diagonal matrices of import coefficients (i.e., proportions of demand imported) for production, consumption and investment, respectively; CD_P and IVX are policy determined public consumption and exogenous investment, in won/year; XD is export demand from the foreign trade component, in won/year; DEPC is capacity depreciation in won/year-year from the capacity component (equation (27)); CKR is the diagonal matrix of capacity - capital ratios, in won/year of capacity per won of capital invested; B is the matrix converting investments in each sector to demands for investment goods from each sector; and I is the identity matrix.

Assuming constant technologies in the nonag sectors, B and all but the first column of A are functions of time, as we'll see in the accounting component (equations (49) and (50)), only by virtue of changing relative prices in the price component. The first column of A, in addition to changing with relative prices, also varies over time as ag technology changes are reflected in ag input demands from KASM.

The second set of constraints consists of the consumption function equations. The rural-urban disaggregation is important in order to capture the effects of differing rural and urban price and income elasticities and changing consumption patterns resulting from different income growth rates in the two areas and from rural-urban migration. Equations (3) and (4) are derived from

$$\frac{\Delta C}{C} = \varepsilon_P \frac{\Delta P}{P} + \varepsilon_Y \frac{\Delta Y}{Y}$$

as discussed in Lloyd Teigen's SEAPA-urban demand paper[4].

(3) $CD_U(t) = POP_U(t)AO_U(t) + POP_U(t)\,A1_U(t)P(t) + S_U(t)A2_U(t)YUL(t)$

(4) $CD_R(t) = POP_R(t)AO_R(t) + POP_R(t)A1_R(t)P(t) + S_R(t)A2_R(t)YRL(t)$

where POP_U and POP_R are scalar-valued urban and rural populations, respectively; P is commodity price indices[5]; and YUL and YRL are exponential averages of urban and rural incomes, respectively, in won/year (equations (75) and (76)). The AO, A1 and A2 depend on the previous values of consumption, price indices and income as described in Teigen's paper.

The third set of constraints relate to the endogenous net investment decisions. Exogenous net investment IVX is determined outside the model, and replacement investment is assumed to equal depreciation. Disinvestment (negative endogenous net investment) is assumed to be limited by depreciation; i.e., disinvestment can't be greater than not replacing depreciated capital.

(5) $IVN(t) \geq -\,CKR^{-1}DEPC(t)$.

Investment decisions will be such that endogenous investment will not exceed the level required to create the desired additional capacity rate DAC (equation (31)), taking into account expectations of exogenous investment.

These expectations are assumed to be an exponential average IVXL of recent exogenous investments (equation (88)).

$$(6) \qquad \frac{dIVN(t)}{dt} \le CKR^{-1} \frac{dDAC(t)}{dt} - \frac{dIVXL(t)}{dt}$$

or in an annual period model

$$(6') \qquad IVN(t) \le IVN(t-1) + CKR^{-1}(DAC(t) - DAC(t-1)) - (IVXL(t) - IVXL(t-1))$$

where desired additional capacity DAC is determined in the capacity component.

Scarce investment funds, determined below in the income constraints, must then be allocated among the sectors within these constraints. It's not clear yet how best to do this. One possibility is an investment equation similar to (3) and (4) with investment a function of sector profits or profits per unit of capacity, perhaps with an additional decision variable similar to S_U and S_R to satisfy the income constraints. Another alternative is to allocate investments through the objective function, e.g., by maximizing discounted projected returns from the additional capacity, as in (7).

$$(7) \qquad \max \quad Z = PPCPD(t)^T \cdot CKR \cdot IVN(t)$$

where PPCPD is the column vector of discounted projected profits per unit of capacity, computed in the accounting component (equation (87)).

Finally, the income constraints assure that consumption is neither greater than total disposable income nor less than the average propensity to consume, that investment is not greater than the average propensity to save less ag investment from KASM, and that total income is accounted for.

$$(8) \quad APC_U \cdot YU(t) \leq \vec{1}^T CD_U(t) \leq YU(t)$$

$$(9) \quad APC_R \cdot YR(t) \leq \vec{1}^T CD_R(t) \leq YR(t)$$

$$(10) \quad \vec{1}^T IVN(t) \leq (1-APC_U)YU(t) + (1-APC_R)YR(t) - AGIV(t)$$

$$(11) \quad \vec{1}^T(CD_U(t) + CD_R(t) + IVN(t)) = YU(t) + YR(t) - AGIV(t)$$

where AGIV is endogenous investment in agriculture from KASM[6]; APC_U and APC_R are average propensities to consume in urban and rural areas, respectively; and $\vec{1}$ is a column vector of 1's.

Note that if investment falls below the average propensity to s ave, the residual income goes to consumption. Also, incomes YU and YR are themselves functions of the decision variables (see the accounting component), so they would be replaced in (8)-(11) by those functions. Finally, no distinction is made as to the source of investment funds, whether from rural or urban income, although the location of investment (in rural or urban areas) is determined in the capacity component.

Equation (11) is another candidate for an objective function. That is, the equality (=) would be replaced by an inequality ($\leq$) and the left-hand side maximized. There would be a problem here, however, in that there would not in general be a unique solution; i.e., the objective function would be parallel to one of the constraints.

Turning now to the issue of the objective function, in addition to the above-mentioned possibilities, a third candidate would be to assume producers seek a desired level of production, DPL. This could either be a constant proportion of total capacity or it could be computed in the capacity component as a function of other variables, e.g., profits, prices or an assumed marginal cost curve. The objective would then be to minimize the difference between actual production OUT and the desired level.

(12) $\min \quad Z = (DPL \cdot CAP(t) - OUT(t))^2$

where OUT is a function of the decision variables as in (2). Note that (12) gives a quadratic programming problem.

Simultaneous Equations Formulation

Because of the theoretical and practical difficulties associated with programming models, the PCI component model presented below as an alternative to the programming formulation changes some of the assumptions in the latter and converts it to a system of simultaneous equations.

First, the production constraint assumes a desired production level (which may or may not be a function of other model variables) will always be attained by producers.

(13) $OUT(t) = DPL(t) \cdot CAP(t)$

where OUT is defined by (2) and DPL is a diagonal matrix of desired production levels.

Equations (3) and (4) remain as the consumption functions except for the following modification, which insures satisfaction of the production constraint (13) by adjusting demand in proportion to the component of demand due to price.

(14) $CD_U(t) = POP_U(t)AO_U(t) + POP_U(t)R(t)A1_U(t)P(t)$
$+ S_U(t)\ A2_U(t)YUL(t)$

(15) $CD_R(t) = POP_R(t)AO_R(t) + POP_R(t)R(t)A1_R(t)P(t)$
$+ S_R(t)A2_R(t)YRL(t)$

where R is a diagonal matrix whose diagonal elements R_d enter the decision vector to satisfy the output constraint.

A similar equation for investment would have

$$(16)\quad IVN(t) = AO_I(t) + \tilde{R}(t)A1_I(t)PPC(t) + S_I(t)A2_I(t)CKR^{-1}DAC(t) - IVXL(t)$$

where the scalar S_I is added to the decision vector to satisfy the income constraint (19). Note that investment adjustments are made 1) in proportion to the component of investment due to capacity to satisfy the income constraint and 2) in proportion to the component of investment due to profitability to satisfy the production constraint. Also, note that expectations of exogenous investment IVXL (see equation (6')) are included.

Finally, the income identities are

$$(17)\quad \vec{1}^T CD_U(t) = APC_U YU(t)$$

$$(18)\quad \vec{1}^T CD_R(t) = APC_R YR(t)$$

$$(19)\quad \vec{1}^T IVN(t) = (1-APC_U)YU(t) + (1-APC_R)YR(t)$$

where, again, IVN_1 = AGIV is determined in KASM.

Thus, eliminating the IVN_1 equation in (16), we have (4n+2) linearly independent equations in (4n+2) unknowns

$$X(t) = [CD_U(t)\ CD_R(t)\ IVN^*(t)\ \tilde{R}_d(t)\ S_U(t)\ S_R(t)\ S_I(t)]^T$$

where IVN* is the (n-1)x1 vector of nonag investments. This compares with the programming formulation with (3n+1) unknowns and at least (5n+2) constraints.

Capacity

The capacity component translates investment into productive capacity in urban and rural areas. It also computes depreciation and projects desired additional capacity to feed back to the PCI component for further investment decisions.

Total net investment.

(20) $TIV(t) = IVN(t) + IVX(t)$,

is divided between urban and rural areas and added to depreciation DEPC to determine gross investment GIV in each area.

(21) $GIV_R(t) = PIR(t)TIV(t) + CKR^{-1}DEPC_R(t)$

(22) $GIV_U(t) = (I-PIR(t))TIV(t) + CKR^{-1}DEPC_U(t)$

where PIR is a diagonal matrix of proportions of investments going to expand nonag capacity in rural areas. PIR is an important policy variable in the Korean context; alternatively, it could be computed endogenously as a function of other model variables.

There is generally a gestation lag between the time the investment decision is made and the time the new capacity becomes productive. The new capacity associated with the investment decision is

(23) $NEWC_i(t) = CKR \cdot GIV_i(t), \; i = R,U$

and the addition to productive capacity ADDC is modeled as a KG^{th}-order distributed delay of NEWC of mean lag time τ_G years.

Similarly, depreciation is a τ_p -year KP^{th}-order distributed delay of ADDC, where τ_p is the average productive life of the additional capacity.

New capacity in gestation and productive capacity are then modeled by the differential equations

(24) $\frac{dCAPG_i(t)}{dt} = NEWC_i(t) - ADDC_i(t) \quad , i = R,U$

(25) $\frac{dCAP_i(t)}{dt} = ADDC_i(t) - DEPC_i(t) \quad , i = R,U.$

In an annual period model, (24) and (25) become

(24') $CAPG_i(t) = CAPG_i(t-1) + NEWC_i(t-1) - ADDC_i(t-1)$

(25') $CAP_i(t) = CAP_i(t-1) + ADDC_i(t-1) - DEPC_i(t-1).$

Total productive capacity, then, is

(26) $CAP(t) = CAP_R(t) + CAP_U(t)$

and total depreciation is

(27) $DEPC(t) = DEPC_R(t) + DEPC_U(t)$

for use in the PCI component. Total gestation capacity CAPG is similarly computed.

In projecting desired additional capacity, the assumption is made that investment decisions are made with a planning horizon τ_H greater than the gestation lag τ_G. Capacity at the end of the planning horizon CAPP is projected linearly from current capacity, assuming present investment levels, by

(28) $$CAPP(t) = CAP(t) + CAPG(t) - \tau_H DEPC(t) + (\tau_H - \tau_G)NEWC(t).$$

Desired capacity at the end of the planning horizon is a function of the projected proportional change in profitability per unit of capacity.

(29) $DCAP(t) = (I+kPPCPR(t))CAP(t)$

where k is a diagonal matrix of proportionality constants and PPCPR is a diagonal matrix of projected proportional increases in profits per unit of capacity. That is,

(30) $$PPCPR_{ii}(t) = \frac{PPCP_i(t) - PPC_i(t)}{PPC_i(t)}$$

where the current (PPC) and projected (PPCP) values of profits per unit of capacity are computed in the accounting component (equations (84) and (85)).

Desired additional capacity per year is spread over $(\tau_H - \tau_G)$ years for investment.

(31) $DAC(t) = (\tau_H - \tau_G)^{-1}(DCAP(t)-CAPP(t))$.

Finally, the desired production level DPL may either be a constant in the model or a function, computed here, of other model variables.

Price

As we have seen, variables in KOMAC are in value units. Thus, if prices were to be determined simultaneously with demand and supply in the PCI component, we would either have consistency problems or serious non-linearities in the linearized model. For example, the input-output technology matrix A would depend on the decision variables (particularly prices); but it is also a coefficient matrix of the decision variables, giving rise to nonlinearities. Alternatively, A could be considered constant at time t, depending only on relative prices at t-1, but that would be inconsistent with output and prices at t, particularly since A(t) determines value added, and hence income, at t. Using A(t-1) would give income at t-1 prices for output at t.

Therefore, it may be safer (and not too unrealistic in any case) to assume supply and demand at time t determine prices for t+1. Note that prices P are actually price indices. For simplicity in the discussion, we'll call them prices.

The consumption functions were, as discussed earlier, derived from

$$\frac{\Delta C}{C} = \epsilon_P \frac{\Delta P}{P} + \epsilon_Y \frac{\Delta Y}{Y}$$

Solving for prices,

$$\frac{\Delta P}{P} = \epsilon_P^{-1} \frac{\Delta C}{C} - \epsilon_P^{-1} \epsilon_Y \frac{\Delta Y}{Y}$$

or

$$P(t+1) = P(t) + \varepsilon_P^{-1} \frac{P(t)}{C(t)} ((C(t+1)-C(t))$$

$$- \varepsilon_P^{-1} \varepsilon_Y \frac{P(t)}{Y(t)} (Y(t+1)-Y(t)).$$

Now, computing P(t+1) at time t, consumption and income at t+1 are not known. If we can make the heroic assumption that changes in consumption and income can be projected as

$$C(t+1) - C(t) = k_C(C(t) - C(t-1))$$

$$Y(t+1) - Y(t) = k_Y(Y(t) - Y(t-1)),$$

then P(t+1) can be approximated by

$$(32) \quad P(t+1) = P(t) + k_C \varepsilon_P^{-1} \frac{P(t)}{C(t)} (C(t)-C(t-1)) - k_Y \varepsilon_P^{-1} \varepsilon_Y \frac{P(t)}{Y(t)} (Y(t)-Y(t-1))$$

where C and Y are per capita consumption and income aggregated across urban and rural areas.

Labor

The labor component computes rural, urban and nonag labor demands and wages. Labor supplies and ag labor demands are determined in KASM.

Labor input per unit output L may decrease over time with increasing labor productivity, where the rate of decrease r may be a constant (e.g., 0), a policy variable or a function of other model variables.

$$(33) \quad \frac{dL(t)}{dt} = -r(t)L(t)$$

where L is in man-hours/won.

Demand for labor in sector i is, then,

$$(34) \quad DL_i(t) = \begin{cases} DLA(t), & i=1 \\ L_i(t)OUT_i(t), & i=2,\ldots,n \end{cases}$$

where DL is in man-hours/year. Nonag labor demand in rural and urban areas and total is

(35) $$DIN_R(t) = \sum_{i=2}^{n} DL_i(t) \frac{CAP_{Ri}(t)}{CAP_i(t)}$$

(36) $$DIN(t) = \sum_{i=2}^{n} DL_i(t)$$

(37) $$DIN_U(t) = DIN(t) - DIN_R(t).$$

Total rural labor demand, then, is

(38) $$DLR(t) = DLA(t) + DIN_R(t).$$

Wage rates in rural and urban areas WR_R and WR_U also may be either constant or computed endogenously as a function of time, other model variables or policy parameters. Given wage rates, the wage bill is

(39) $$W_R(t) = WR_R(t)DL(t) \frac{CAP_R(t)}{CAP(t)}$$

(40) $$W_U(t) = WR_U(t)DL(t) \frac{CAP_U(t)}{CAP(t)}$$

(41) $$W(t) = W_R(t) + W_U(t)$$

(42) $$TW(t) = \vec{1}^T W(t)$$

(43) $$TW_R(t) = \vec{1}^T W_R(t)$$

(44) $$TW_U(t) = TW(t) - TW_R(t)$$

where wages are in won/year. W is wages by sector, and TW is total wages.

Foreign Trade

Foreign trade and trade balances are central policy issues in Korea. This component of KOMAC is still very open pending identification of the key policy instruments and objectives. It may be desirable to keep this component somewhat open so policy analysts can interact directly with the model in specifying the foreign trade variables.

Referring back to the production function (2), we see that foreign trade variables are PMC, CMC, IMC and XD. To the extent that IVX includes a foreign investment component, it may also be of interest here.

Production and investment import coefficients -- PMC and IMC, respectively -- are linear combinations of 1970 (or other initial time) levels and those portions of 1970 levels representing non-competitive imports.

(45) $PMC(t) = ISP(t)PMCT + (I-ISP(t))PMCC$

(46) $IMC(t) = ISI(t)IMCT + (I-ISI(t))IMCC$

where PMCT and PMCC are diagonal matrices of total production import proportions in 1970 and non-competitive production import proportions in 1970, respectively. Similarly for IMCT and IMCC.

The diagonal matrices of import substitution coefficients ISP and ISI are open for policy specification over time or may be functions of other variables, such as import and export prices, inflation rates, foreign trade balances, etc.

Since we cannot assume fixed "technologies" for consumption as we do for production and investment -- i.e., we can't assume a constant proportion of consumption as non-competitive imports -- CMC is computed differently.

$$(47) \quad CMC(t) = ISC(t)CMCT$$

where CMCT is 1970 consumption import proportions.

While ISI, ISP and ISC are policy specified, they must logically conform to the constraints:

$$\emptyset \leq ISI(t) \leq I$$

$$\emptyset \leq ISP(t) \leq I$$

$$\emptyset \leq ISC(t) \leq CMCT^{-1}$$

where $\emptyset$ is the null matrix.

The vector of export demands XD and a diagonal matrix of import tax rates TXMR are also open for policy specification or to be made endogenous functions.

Finally, given an exogenously determined time path for export prices XP, import prices can be computed as

$$(48) \quad IP(t) = (I+TXMR(t))XP(t) + TC(t)$$

where TC is transport costs.

Note that public consumption CD_P and exogenous investment, while not necessarily foreign trade issues, are exogenous policy inputs to KOMAC.

Accounting

The accounting component plays a big role by computing variables to feed back within KOMAC, to output as performance criteria (e.g., national accounts) and to link with KASM.

Given price indices from the price component, the input-output technology matrix $A=[a_{ij}]$ and the investment demand matrix $B=[b_{ij}]$ are updated by

$$(49) \qquad a_{ij}(t) = \begin{cases} a_{ij}(0)\,\dfrac{P_i(t)}{P_j(t)}, & i=1,\ldots,n;\ j=2,\ldots,n \\[2ex] \dfrac{AINP_i(t)}{OUTA(t)}, & i=1,\ldots,n;\ j=1 \end{cases}$$

$$(50) \qquad b_{ij}(t) = b_{ij}(0)P_i(t) \quad \text{for all } i,\ j$$

where AINP are ag input demands and OUTA is total ag output, both in won/year.

Value added per unit of output VAU is a diagonal matrix whose diagonal elements are

$$(51) \qquad VAU_{ii}(t) = 1 - \sum_{k=1}^{n} a_{ki}(t),$$

i.e., one minus the sum of the i^{th} column of A.

Sector and total value added in rural and urban areas and nationally are, then,

$$(52) \qquad VA_R(t) = VAU(t)OUT(t)\,\frac{CAP_R(t)}{CAP(t)}$$

$$(53) \qquad VA(t) = VAU(t)OUT(t)$$

$$(54) \qquad VA_U(t) = VA(t) - VA_R(t)$$

$$(55) \qquad TVA(t) = \vec{1}^T VA(t)$$

$$(56) \qquad TVA_R(t) = \vec{1}^T VA_R(t)$$

$$(57) \qquad TVA_U(t) = TVA(t) - TVA_R(t).$$

Ag and nonag value added, respectively are

$$(58) \qquad TVAA(t) = VA_1(t)$$

$$(59) \qquad TVAN(t) = TVA(t) - TVAA(t).$$

Sector profits are value added less wages, indirect taxes and depreciation (capital consumption allowance).

(60) $$PROF_R(t) = VA_R(t) - W_R(t) - INTX_R(t) - CKR^{-1}DEPC_R(t).$$

Indirect taxes are

(61) $$INTX_R(t) = INTXR(t)OUT(t)\cdot\frac{CAP_R(t)}{CAP(t)}$$

where INTXR is the indirect (e.g., sales) tax rate. Similar equations hold for the urban sectors, and sector and national totals PROF, $TPROF_R$, $TPROF_U$ and TPROF are also computed.

Total income is wages plus profits and disposable income is total less income taxes. Income is disaggregated by ag-nonag and rural-urban sectors. First, ag and rural and urban nonag incomes are

(62) $$YA(t) = W_1(t) + PROF_1(t)$$

(63) $$YN_R(t) = \sum_{i=2}^{n} W_{Ri}(t) + PROF_{Ri}(t)$$

(64) $$YN_U(t) = \sum_{i=2}^{n} W_{Ui}(t) + PROF_{Ui}(t)$$

(65) $$YN(t) = YN_R(t) + YN_U(t)$$

(66) $$TYR(t) = (1-RYT_{RU})\ (YA(t)+YN_R(t)) + PYT_{UR}YN_U(t)$$

(67) $$TYU(t) = YA(t) + YN(t) - TYR(t)$$

where PYT_{RU} and PYT_{UR} are proportions of rural and urban incomes, respectively, transferred to urban and rural areas; e.g., for family support, but not investment.

Income taxes YTX and disposable incomes YU and YR are

(68) $YTX(t) = YTXR(TYU(t) + TYR(t))$

(69) $YU(t) = (1-YTXR)TYU(t)$

(70) $YR(t) = (1-YTXR)TYR(t).$

Rural and urban disposable income per capita and ag and nonag income per worker are

(71) $YUP(t) = YU(t)/POP_U(t)$

(72) $YRP(t) = YR(t)/POP_R(t)$

(73) $YNW(t) = YN(t)/DLN(t)$

(74) $YAW(t) = YA(t)/DLA(t).$

Exponentially averaged values of YU and YR needed in the consumption functions (equations (3), (4), (14) and (15)) are

(75) $$\frac{dYUL(t)}{dt} = \frac{1}{\tau_{YL}} (YU(t) - YUL(t))$$

(76) $$\frac{dYRL(t)}{dt} = \frac{1}{\tau_{YL}} (YR(t) - YRL(t)).$$

The ag and nonag price indices needed in KASM, and the general price index, are

(77) $PA(t) = P_1(t)$

(78) $$PN(t) = \frac{\sum_{i=2}^{n} P_i(t)OUT_i(t)}{\sum_{i=2}^{n} OUT_i(t)}$$

(79) $$GPX(t) = \frac{\sum_{i=1}^{n} P_i(t)OUT_i(t)}{\sum_{i=1}^{n} OUT_i(t)}$$

Aggregate per capita rural and urban demands for ag and nonag commodities needed by KASM are

(80) $\quad PCDA_R(t) = CD_{R1}(t)/POP_R(t)$

(81) $\quad PCDA_U(t) = CD_{U1}(t)/POP_U(t)$

(82) $\quad PCIN_R(t) = \sum_{i=2}^{n} CD_{Ri}(t)/POP_R(t)$

(83) $\quad PCIN_U(t) = \sum_{i=2}^{n} CD_{Ui}(t)/POP_U(t).$

Profits per unit of capacity for time t (PPC) and projected for the end of the planning horizon (PPCP) — needed in the PCI and capacity components for investment decisions (equations (7), (16) and (30)) — are

(84) $\quad PPC(t) = PROF(t)/CAP(t)$

(85) $\quad PPCP(t) = PPCL(t) + \tau_H \dfrac{dPPCL(t)}{dt}$

The exponentially averaged value of PPC and discounted value of PPCP (for equation (7)) are

(86) $\quad \dfrac{dPPCL(t)}{dt} = \dfrac{1}{\tau_{PL}} (PPC(t) - PPCL(t))$

(87) $\quad PPCPD(t) = PPCP(t)/(1+\rho)^{\tau_H}$

where ρ is the discount rate.

Investment equations (6) and (16) use the exponential average of exogenous investment as expectations:

(88) $\quad \dfrac{dIVXL(t)}{dt} = \dfrac{1}{\tau_{IVX}} (IVX(t) - IVXL(t)).$

Finally, national accounting variables are computed, including balance of trade and gross domestic product.

Production, consumption, investment and total import demands are

(89) $PM(t) = PMC(t)A(t)OUT(t)$

(90) $CM(t) = CMC(t)\ (CD_U(t) + CD_R(t))$

(91) $IM(t) = IMC(t)B(t)(GIV_U(t) + GIV_R(t))$

(92) $MD(t) = PM(t) + CM(t) + IM(t).$

Total imports, exports and the trade balance are

(93) $TMD(t) = \vec{1}^T MD(t)$

(94) $TXD(t) = \vec{1}^T XD(t)$

(95) $TRDBAL(t) = TXD(t) - TMD(t).$

Import duties by sector and total are

(96) $MTX(t) = TXMR(t)MD(t)$

(97) $TMTX(t) = \vec{1}^T MTX(t).$

At last, total and per capita gross domestic product are

(98) $GDP(t) = TVA(t) - TMTX(t)$

(99) $GDPP(t) = GDP(t)/(POP_U(t)+POP_R(t)).$

If desired, growth rates — real and nominal, total and per capita — can also be computed.

OPERATIONALIZATION OF KOMAC.

There are three issue areas concerning the operationalization of KOMAC which can be identified at this time: the definition of economic sectors; data requirements; and linkage with KASM.

Defining the nonagricultural sectors is, of course, of crucial importance. KASS Working Paper 74-1 by Teigen and Suh[7] develops a 19-sector input-output model of the Korean economy, aggregated from a 56-sector Bank of Korea model which in turn was an aggregation of a 340-sector model. Five of Teigen and Suh's 19 sectors (six if forestry is included) are agricultural: rice, barley and wheat; other grains, fruits and vegetables; industrial crops; livestock; and fishery. I discussed earlier the desirability of a single ag sector for KASM purposes.

The Byerlee-Halter model favors a disaggregation by scale of operation, where small-scale firms employ primarily self-employed entrepreneurs and generally less than ten hired workers while large-scale firms employ large labor forces with institutionally fixed wage rates. Thus, for example, the manufacturing and services sectors are both split into small and large scale, making four sectors. (In addition, there is a residual agricultural sector for ag activities not considered in the ag sector model). In this way, the model gives an indication of urban unemployment and underemployment and of income distribution problems.

In the Korean context, however, the most crucial issues are agricultural production in search of food self-sufficiency and stimulation of export industries and discouragement of imports in search of favorable foreign exchange balances. Therefore, a nonagricultural sector disaggregation emphasizing ag input industries; ag processing industries and export industries would seem to be a useful break-down. Insofar as this would entail a redefinition of the Teigen-Suh sectors, it may be necessary to go back to the 340-sector model for re-aggregation.

Data requirements are, of course, as for most large-scale models, momentous. Teigen and Suh have laid the ground-work for much of it in terms of the input-output technology matrix A(1970), the investment demand matrix B(1970) and the import coefficient matrices PMCT, PMCC, IMCT, IMCC and CMCT. These would have to be re-specified, however, if the sectors are redefined.

A large task will be to estimate the income and own-and cross-price elasticities of demand in the rural and urban areas for the consumption functions. An aggregation of these is also needed across both areas for the price function. In addition, the model requires "elasticities" of investment with respect to profits per unit capacity and to desired additional capacity for the investment function.

While the above present the biggest data challenges, various others are: the capacity-capital ratios; orders and time lags of the capacity gestation and production delays; and labor input requirements.

Finally, in linking KASM and KOMAC, one observation that can be made at this time is that it appears consistency should be from the top down. That is, KOMAC should be executed <u>before</u> the rural and urban demand components of KASM so disaggregated food consumption decisions in the latter can be made consistent with aggregate ag and nonag consumption from KOMAC. Essentially, urban income is an input to the food demand component; thus, KOMAC must be executed first. Also, individual food price <u>levels</u> should be consistent with the aggregate ag price <u>index</u> from KOMAC.

N O T E S

1 Derek Byerlee and Albert N. Halter, "A Macro-Economic Model for Agricultural Sector Analysis", submitted to the American Journal of Agricultural Economics for publication, 1974.

2 Personal communication.

3 All values are in constant won unless otherwise stated. Also, all variables are nxl vectors unless otherwise stated.

4 Lloyd D. Teigen, "The Annual Price Determination Mechanism", KASS Working Paper 74-2, June 19, 1974.

5 See the price component, equation (32).

6 In fact, $IVN_1(t) = AGIV(t)$, so that IVN_1 is not a decision variable in this component.

7 Lloyd D. Teigen and Suh, Han Hyeck, "An Aggregated Input-Output Model for Korea Emphasizing Agriculture", KASS Working Paper 74-1, 26 March 1974.